ZOOM LENS SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a zoom lens system for photographic camera, and in particular, relates to a zoom lens system for a lens-shutter camera.

2. Description of the Prior Art

Unlike a zoom lens system of a single lens reflex (SLR) camera which requires space to accommodate a quick-return mirror behind the photographing lens system, a zoom lens system of a compact camera does not require a long back focal distance. As an example of such a zoom lens system of a compact camera having few constrains on the back focal distance, a zoom lens system of a three-lens-group arrangement, i.e., a positive lens group, another positive lens group, and a negative lens group, in this order from the object, has been proposed (e.g., Japanese Unexamined Patent Publication No. Hei-2-256015). However, if an attempt is made to further increase the zoom ratio in such a zoom lens system mentioned above, the overall length of the zoom lens system becomes longer at the long focal length extremity.

Furthermore, for the purpose of achieving further

miniaturization and a higher zoom ratio, a zoom lens system of a four-lens-group arrangement, i.e., a positive lens group, a negative lens group, a positive lens group and a negative lens group, in this order from the object, has been proposed (e.g., Japanese Unexamined Patent Publications No. Hei-6-265788 and No. 2000-180725). However, in such a lens arrangement, the traveling distances of the lens groups thereof are longer, so that the overall length of the zoom lens system at the long focal length extremity becomes longer; and the entrance pupil position becomes distant at the short focal length extremity, so that the frontmost lens diameter becomes larger. Consequently, further miniaturization cannot be achieved.

SUMMARY OF THE INVENTION

The present invention provides a zoom lens system, for a lens-shutter compact camera with a retractable lens barrel, having a zoom ratio Z ($= f_T / f_W$) of more than 3.5.

According to the present invention, there is provided a zoom lens system including a first lens group having a positive refractive power (hereinafter, positive first lens group), a second lens group having a negative refractive power (hereinafter, negative second lens group), a third lens group having a positive refractive power

(hereinafter, positive third lens group), and a fourth lens group having a negative refractive power (hereinafter, negative fourth lens group), in this order from the object.

Zooming is performed by moving each of the positive first through the negative fourth lens groups along the optical axis.

The zoom lens system satisfies the following condition:

$$0.35 < (f_{23T}/f_{23W})/(f_T / f_W) < 0.55 \quad \ldots \quad (1)$$

wherein

f_{23T} designates the combined focal length of the negative second lens group and the positive third lens group at the long focal length extremity;

f_{23W} designates the combined focal length of the negative second lens group and the positive third lens group at the short focal length extremity;

f_T designates the focal length of the entire the zoom lens system at the long focal length extremity; and

f_W designates the focal length of the entire the zoom lens system at the short focal length extremity.

The zoom lens system preferably satisfies the following condition:

$$0.05 < (D_{23W} - D_{23T})/ f_W < 0.2 \quad \ldots \quad (2)$$

wherein

D_{23W} designates the axial distance between the

negative second lens group and the positive third lens group at the short focal length extremity;

D_{23T} designates the axial distance between the negative second and the positive third lens group at the long focal length extremity; and

f_W designates the focal length of the entire the zoom lens system at the short focal length extremity.

The zoom lens system can satisfy the following condition:

$0.5 < f_W / f_{1G} < 0.7$ ... (3)

wherein

f_W designates the focal length of the entire the zoom lens system at the short focal length extremity; and

f_{1G} designates the focal length of the positive first lens group.

The zoom lens system preferably satisfies the following condition:

$12\ \mathrm{mm} < f_{4G}(m_{4T} - m_{4W})/(f_T / f_W) < 14\ \mathrm{mm}$ ... (4)

wherein

f_{4G} designates the focal length of the negative fourth lens group;

m_{4T} designates the magnification of the negative fourth lens group when an object at an infinite distance is in an in-focus state at the long focal length extremity;

m_{4W} designates the magnification of the negative

fourth lens group when an object at an infinite distance is in an in-focus state at the short focal length extremity;

f_T designates the focal length of the entire the zoom lens system at the long focal length extremity; and

f_W designates the focal length of the entire the zoom lens system at the short focal length extremity.

The zoom lens system of the present invention can be applied to a zoom lens system in which (i) the negative second lens group and the positive third lens group are arranged to maintain a predetermined distance d1 in a short-focal-length side zooming range which is defined between the short focal length extremity and a first (before switching) intermediate focal length, and to maintain another predetermined distance d2, which is smaller than the predetermined distance d1, in a long-focal-length side zooming range which is defined between a second (after switching) intermediate focal length and the long focal length extremity; (ii) at the first (before switching) intermediate focal length, all the lens groups are moved toward an image to the second (after switching) intermediate focal length; and (iii) the zoom lens system preferably satisfies the following condition:

$$12mm < (X_{4W} + X_{4T} - \Delta X_{4MM*})/(f_T / f_W) < 14mm \quad \ldots \quad (5)$$

wherein

$X_{4W} = f_{4G} (m_{4M} - m_{4W})$;

$X_{4T} = f_{4G} (m_{4T} - m_{4M*})$;

$\Delta X_{4MM*} = f_{4G} (m_{4T} - m_{4M*})$;

$m_{4M} = fm/f_{123M}$;

$m_{4W} = f_W/f_{123W}$;

$m_{4T} = f_T/f_{123T}$;

$m_{4M*} = fm'/f_{123M*}$;

fm designates the first intermediate focal length;

fm' designates the second intermediate focal length;

f_{123W} designates the combined focal length of the positive first lens group, the negative second lens group and the positive third lens group at the short focal length extremity;

f_{123M} designates the combined focal length of the positive first lens group, the negative second lens group and the positive third lens group at the first (before switching) intermediate focal length in the short-focal-length side zooming range;

f_{123M*} designates the combined focal length of the positive first lens group, the negative second lens group and the positive third lens group at the second (after switching) intermediate focal length in the long-focal-length side zooming range;

f_{123T} designates the combined focal length of the

positive first lens group, the negative second lens group and the positive third lens group at the long focal length extremity;

f_T designates the focal length of the entire the zoom lens system at the long focal length extremity; and

f_W designates the focal length of the entire the zoom lens system at the short focal length extremity.

In the zoom lens system, the positive third lens group preferably includes at least one aspherical surface which satisfies the following condition:

$-30 < \Delta I_{ASP} < -10$ ... (6)

wherein

ΔI_{ASP} designates the amount of change of the spherical aberration coefficient due to the aspherical surface in the positive third lens group under the condition that the focal length at the short focal length extremity is converted to 1.0.

In the zoom lens system, the negative fourth lens group preferably includes at least one aspherical surface which satisfies the following condition:

$0 < \Delta V_{ASP} < 3$ ... (7)

wherein

ΔV_{ASP} designates the amount of change of the distortion coefficient due to the aspherical surface in the negative fourth lens group under the condition that

the focal length at the short focal length extremity is converted to 1.0.

The present disclosure relates to subject matter contained in Japanese Patent Application No.2002-348570 (filed on November 29, 2002) which is expressly incorporated herein in its entirety.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be discussed below in detail with reference to the accompanying drawings, in which:

Figure 1 is a lens arrangement of the zoom lens system according to a first embodiment of the present invention;

Figures 2A, 2B, 2C and 2D show aberrations occurred in the zoom lens system shown in figure 1 at the short focal length extremity;

Figures 3A, 3B, 3C and 3D show aberrations occurred in the zoom lens system shown in figure 1 at the intermediate focal length when the lens groups are moved along the lens-group moving paths shown in figure 20;

Figures 4A, 4B, 4C and 4D show aberrations occurred in the zoom lens system shown in figure 1 at the long focal length extremity;

Figures 5A, 5B, 5C and 5D show aberrations occurred

in the zoom lens system shown in figure 1 at the first (before switching) intermediate focal length in the short-focal-length side zooming range when the lens groups are moved along the lens-group moving paths shown in figure 19;

Figures 6A, 6B, 6C and 6D show aberrations occurred in the zoom lens system shown in figure 1 at the second (after switching) intermediate focal length in the long-focal-length side zooming range when the lens groups are moved along the lens-group moving paths shown in figure 19;

Figure 7 is a lens arrangement of the zoom lens system according to a second embodiment of the present invention;

Figures 8A, 8B, 8C and 8D show aberrations occurred in the zoom lens system shown in figure 7 at the short focal length extremity;

Figures 9A, 9B, 9C and 9D show aberrations occurred in the zoom lens system shown in figure 7 at the intermediate focal length when the lens groups are moved along the lens-group moving paths shown in figure 20;

Figures 10A, 10B, 10C and 10D show aberrations occurred in the zoom lens system shown in figure 7 at the long focal length extremity;

Figures 11A, 11B, 11C and 11D show aberrations

occurred in the zoom lens system shown in figure 7 at the first (before switching) intermediate focal length in the short-focal-length side zooming range when the lens groups are moved along the lens-group moving paths shown in figure 19;

Figures 12A, 12B, 12C and 12D show aberrations occurred in the zoom lens system shown in figure 7 at the second (after switching) intermediate focal length in the long-focal-length side zooming range when the lens groups are moved along the lens-group moving paths shown in figure 19;

Figure 13 is a lens arrangement of the zoom lens system according to a third embodiment of the present invention;

Figures 14A, 14B, 14C and 14D show aberrations occurred in the zoom lens system shown in figure 13 at the short focal length extremity;

Figures 15A, 15B, 15C and 15D show aberrations occurred in the zoom lens system shown in figure 13 at the intermediate focal length when the lens groups are moved along the lens-group moving paths shown in figure 20;

Figures 16A, 16B, 16C and 16D show aberrations occurred in the zoom lens system shown in figure 13 at the long focal length extremity;

Figures 17A, 17B, 17C and 17D show aberrations

occurred in the zoom lens system shown in figure 13 at the first (before switching) intermediate focal length in the short-focal-length side zooming range when the lens groups are moved along the lens-group moving paths shown in figure 19;

Figures 18A, 18B, 18C and 18D show aberrations occurred in the zoom lens system shown in figure 13 at the second (after switching) intermediate focal length in the long-focal-length side zooming range when the lens groups are moved along the lens-group moving paths shown in figure 19;

Figure 19 is the schematic view of the lens-group moving paths, with the switching movement of the lens groups, for the zoom lens system according to the present invention; and

Figure 20 is another schematic view of the lens-group moving paths, without the switching movement of the lens groups, for the zoom lens system according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in the lens-group moving paths of figures 19 and 20, the four-lens-group zoom lens system for a compact camera includes a positive first lens group 10, a negative second lens group 20, a positive third lens group

30, and a negative fourth lens group 40, in this order from the object; and zooming is performed by moving the first through fourth lens groups in the optical axis direction. A diaphragm S is provided between the positive third lens group 30 and the negative fourth lens group 40, and moves together with the positive third lens group 30.

Figure 19 is an example of the lens-group moving paths having a switching movement of the lens groups at the intermediate focal lengths. According to figure 19, zooming from the short focal length extremity fw toward the long focal length extremity ft, the lens groups 10 through 40 are arranged to move as follows:

In a focal-length range ZW (the first focal length range; the short-focal-length side zooming range) extending from the short focal length extremity fw to the first intermediate focal length fm, the positive first lens group 10, the negative second lens group 20, the positive third lens group 30, and the negative fourth lens group 40 are moved toward the object;

At the first intermediate focal length fm (before switching), the positive first lens group 10, the negative second lens group 20, the positive third lens group 30, and the negative fourth lens group 40 are moved towards the image plane by a predetermined distance, so that the first intermediate focal length fm is changed to

the second intermediate focal length fm′ (after switching);

In a focal-length range ZT (the second focal length range; the long-focal-length side zooming range) extending from the second intermediate focal length fm′ to the long focal length extremity ft, the positive first lens group 10, the negative second lens group 20, the positive third lens group 30, and the negative fourth lens group 40 are moved towards the object;

In the focal-length range ZW, the negative second lens group 20 and the positive third lens group 30 maintains a predetermined distance d1 (the first state);

At the first intermediate focal length fm, the distance d1 between the negative second lens group 20 and the positive third lens group 30 is reduced; and

In the focal-length range ZT, the negative second lens group 20 and the positive third lens group 30 maintain the shortened distance d2 (the second state).

The first intermediate focal length fm belongs to the first focal length range ZW.

The second intermediate focal length fm′ is determined after the following movement of the lens groups is completed:

(i) the positive first lens group 10 and the negative fourth lens group 40 are moved from the positions thereof, corresponding to the first intermediate focal length fm,

toward the image; and

(ii) the negative second lens group 20 and the positive third lens group 30 reduce the distance therebetween, while the negative second lens group 20 and the positive third lens group 30 are respectively moved toward the image.

Upon zooming, the diaphragm S moves together with the positive third lens group 30.

The lens-group moving paths, before and after the switching movement, for the first through fourth lens groups shown in figure 19 are simply depicted as straight lines. It should however be noted that actual lens-group moving paths are not necessarily straight lines. Furthermore, focusing is performed by integrally moving the negative second lens group 20 the positive third lens group 30 regardless of the focal length ranges.

The lens-group moving paths have discontinuities at the first intermediate focal length fm and the second intermediate focal length fm'; however, by adequately determining the positions of the positive first lens group 10, the negative second lens group 20, the positive third lens group 30, and the negative fourth lens group 40 respectively at the short focal length extremity fw, the first intermediate focal length fm, the second intermediate focal length fm' and the long focal length

extremity ft, solutions by which an image is correctly formed on the image plane can be obtained.

According to the lens-group moving paths with these solutions, the position of each lens group can be precisely controlled, compared with the lens-group moving paths of figure 20 to be discussed below by which the lens groups are continually moved. Consequently, a zoom lens system which is miniaturized and has a higher zoom ratio can be obtained.

Furthermore, positions for stopping each lens group can be determined in a stepwise manner along the lens-group moving paths of figure 19. In an actual mechanical arrangement of the zoom lens system, each lens group can be stopped at predetermined positions according to the above-explained stepwise manner. For example, if positions at which each lens group is to be stopped are determined by appropriately selecting positions before and after the first (second) intermediate focal length fm (fm'), i.e., not at the positions just corresponding to the first (second) intermediate focal length fm (fm'), the above discontinuities can be connected by smooth curved lines. Moreover, if a stopping position closest to the second intermediate focal length fm' in the long-focal-length side zooming range ZT is set closer to the object from a stopping position closest to the first

intermediate focal length fm in the short-focal-length side zooming range ZW, precision on the movement of the lens groups can be enhanced, since a U-turn movement is prevented in actual moving paths.

Figure 20 shows an example of the lens-group moving paths without intermediate-switching of the focal lengths. Upon zooming from the short focal length extremity toward the long focal length extremity, all the lens groups move toward the object, while the distances therebetween are varied. The diaphragm S is provided between the positive third lens group 30 and the negative fourth lens group 40, and moves together with the positive third lens group 30. The lens-group moving paths of figure 20 are also simply depicted as straight lines; however actual lens-group moving paths are not necessarily straight lines. Furthermore, focusing is performed by integrally moving the negative second lens group 20 and the positive third lens group 30 regardless of the focal length ranges.

Even if the lens-group moving paths of figure 20 are employed, the position of each lens group can be precisely controlled, so that a higher zoom ratio and further miniaturization can be achieved.

Condition (1) specifies the ratio of the combined focal length of the negative second lens group 20 and the

positive third lens group 30 at the short focal length extremity to the combined focal length thereof at the long focal length extremity in order to make the zoom ratio larger. By satisfying this condition, a higher zoom ratio can be achieved.

In a four-lens-group arrangement, it is preferable that the combined focal length of the negative second lens group 20 and the positive third lens group 30 be varied adequately at the short and long focal length extremities, when an attempt is made to increase the zoom ratio, and to avoid an increase in the overall length of the zoom lens system,

If $(f_{23T}/f_{23W})/(f_T / f_W)$ exceeds the upper limit of condition (1), the zooming effect of both the negative second lens group 20 and the positive third lens group 30 becomes too large. Consequently, aberrations in each lens group become larger to the extent that the correcting thereof is difficult.

If $(f_{23T}/f_{23W})/(f_T / f_W)$ exceeds the lower limit of condition (1), it becomes difficult to obtain a higher zoom ratio.

Condition (2) specifies the amount of change in the distance, upon zooming, between the negative second lens group 20 and the positive third lens group 30. By satisfying this condition, the zoom ratio can be made

larger without increasing the overall length of the zoom lens system.

If $(D_{23W} - D_{23T}) / f_W$ exceeds the upper limit of condition (2), the amount of change in the distance between the negative second lens group 20 and the third lens group 30 becomes larger, and the overall length of the zoom lens system becomes longer.

If $(D_{23W} - D_{23T}) / f_W$ exceeds the lower limit of condition (2), the zooming effect of both the negative second lens group 20 and the positive third lens group 30 becomes smaller. Consequently, a higher zoom ratio cannot be achieved without increasing the overall length of the zoom lens system.

Condition (3) specifies the ratio of the focal length of the entire the zoom lens system at the short focal length extremity to the focal length of the positive first lens group 10 for the purpose of achieving further miniaturization. By satisfying this condition, the traveling distance of the positive first lens group 10 can be made shorter, so that the zoom lens system can be further miniaturized.

If the focal length of the positive first lens group 10 becomes shorter to the extent that f_W / f_{1G} exceeds the upper limit of condition (3), aberrations occurred in the positive first lens group 10 become larger, so that the

correcting of aberrations becomes difficult.

If the focal length of the positive first lens group 10 becomes longer to the extent that f_W / f_{1G} exceeds the lower limit of condition (3), the traveling distance of the positive first lens group 10 becomes longer, and further miniaturization cannot be achieved.

Condition (4) specifies the traveling distance of the negative fourth lens group 40 in the case where the lens groups of the zoom lens system are arranged to move along the lens-group moving paths shown in figure 20. By satisfying this condition, the traveling distance of the negative fourth lens group 40 can be made shorter, and further miniaturization of the zoom lens system can be achieved.

If the traveling distance of the negative fourth lens group 40 becomes longer to the extent that $f_{4G}(m_{4T} - m_{4W})/(f_T / f_W)$ exceeds the upper limit of condition (4), further miniaturization of the zoom lens system becomes difficult.

If the traveling distance of the negative fourth lens group 40 becomes shorter to the extent that $f_{4G}(m_{4T} - m_{4W})/(f_T / f_W)$ exceeds the lower limit of condition (4), it becomes difficult to achieve a zoom ratio of about 3.5.

Condition (5) specifies the traveling distance of the negative fourth lens group 40 in the case where the lens groups of the zoom lens system are arranged to move along

the lens-group moving paths, shown in figure 19, having a switching movement of the lens groups. By satisfying this condition, the traveling distance of the negative fourth lens group 40 can be made shorter, and further miniaturization of the zoom lens system can be achieved.

If the traveling distance of the negative fourth lens group 40 becomes longer to the extent that $(X_{4W} + X_{4T} - \Delta X_{4MM*}) / (f_T / f_W)$ exceeds the upper limit of condition (5), further miniaturization of the zoom lens system becomes difficult.

If the traveling distance of the negative fourth lens group 40 becomes shorter to the extent that $(X_{4W} + X_{4T} - \Delta X_{4MM*})/(f_T / f_W)$ exceeds the lower limit of condition (5), it becomes difficult to achieve a zoom ratio of about 3.5.

Condition (6) specifies the amount of asphericity in the case where the positive third lens group 30 includes at least one aspherical surface. By satisfying this condition, spherical aberrations can be adequately corrected.

If the amount of asphericity becomes larger to the extent that ΔI_{ASP} exceeds the upper limit of condition (6), manufacture of the lens element having the aspherical surface becomes difficult.

If the amount of asphericity becomes smaller to the extent that ΔI_{ASP} exceeds the lower limit of condition (6), the amount of the correcting of spherical aberration by

the aspherical surface becomes smaller, so that the correcting of aspherical aberration cannot be made sufficiently.

Condition (7) specifies the amount of asphericity in the case where the negative fourth lens group 40 includes at least one aspherical surface. By satisfying this condition, distortion can be adequately corrected.

If the amount of asphericity becomes larger to the extent that ΔV_{ASP} exceeds the upper limit of condition (7), manufacture of the lens element having the aspherical surface becomes difficult.

If the amount of asphericity becomes smaller to the extent that ΔV_{ASP} exceeds the lower limit of condition (7), the amount of the correcting of distortion by the aspherical surface becomes smaller, so that the correcting of distortion cannot be made sufficiently.

Specific numerical data of the embodiments will be described hereinafter. In the diagrams of chromatic aberration (axial chromatic aberration) represented by spherical aberration, the solid line and the two types of dotted lines respectively indicate spherical aberrations with respect to the d, g and C lines. Also, in the diagrams of lateral chromatic aberration, the two types of dotted lines respectively indicate magnification with respect to the g and C lines; however, the d line as the base line

coincides with the ordinate. In the diagrams of astigmatism, S designates the sagittal image, and M designates the meridional image. In the tables, F_{NO} designates the f-number, f designates the focal length of the entire zoom lens system, f_B designates the back focal distance, W designates the half angle-of-view (°), r designates the radius of curvature, d designates the lens-element thickness or distance between lens elements, N_d designates the refractive index of the d-line, and ν designates the Abbe number.

In addition to the above, an aspherical surface which is symmetrical with respect to the optical axis is defined as follows:

$$x = cy^2/(1+[1-\{1+K\}c^2y^2]^{1/2})+A4y^4+A6y^6+A8y^8+A10y^{10}....$$

wherein:

c designates a curvature of the aspherical vertex (1/r);

y designates a distance from the optical axis;

K designates the conic coefficient; and

A4 designates a fourth-order aspherical coefficient;

A6 designates a sixth-order aspherical coefficient;

A8 designates a eighth-order aspherical coefficient; and

A10 designates a tenth-order aspherical coefficient.

Furthermore, the relationship between the aspherical coefficients and aberration coefficients is

discussed as follows:

1. The shape of an aspherical surface is defined as follows:

$$x=cy^2/(1+[1\{1+K\}c^2y^2]^{1/2})+A4y^4+A6y^6+A8y^8+A10y^{10}...$$

wherein:

x designates a distance from a tangent plane of an aspherical vertex;

y designates a distance from the optical axis;

c designates a curvature of the aspherical vertex (1/r),

K designates a conic constant;

2. In this equation, to obtain the aberration coefficients, the following substitution is made to replace K with "0" (Bi=Ai when K=0).

$$B4 = A4+Kc^3/8;$$

$$B6 = A6+(K^2+2K)c^5/16;$$

$$B8 = A8+5(K^3+3K^2+3K)c^7/128$$

$$B10 = A10+7(K^4+4K^3+6K^2+4K)c^9/256;$$ and therefore, the following equation is obtained:

$$x = cy^2/[1+[1-c^2y^2]^{1/2}]+B4y^4+B6y^6+B8y^8+B10y^{10}+...$$

3. Furthermore, in order to normalize the focal length f to 1.0, the followings are considered:

$$X = x/f; \quad Y = y/f; \quad C = f*c;$$

$$\alpha 4 = f^3B4; \quad \alpha 6 = f^5B6; \quad \alpha 8 = f^7B8; \quad \alpha 10 = f^9B10$$

Accordingly, the following equation is obtained.

$$X = CY^2/[1+[1-C^2Y^2]^{1/2}]+\alpha 4Y^4+\alpha 6Y^6+\alpha 8Y^8+\alpha 10Y^{10}+...$$

4. $\Phi = 8(N'-N)\alpha 4$ is defined, and the third aberration coefficients are defined as follows:

I designates the spherical aberration coefficient;

II designates the coma coefficient;

III designates the astigmatism coefficient;

IV designates the curvature coefficient of the sagittal image surface; and

V designates a distortion coefficient; and therefore, the influence of the fourth-order aspherical-surface coefficient ($\alpha 4$) on each aberration coefficient is defined as:

$\Delta I = h^4\Phi$

$\Delta II = h^3k\Phi$

$\Delta III = h^2k^2\Phi$

$\Delta IV = h^2k^2\Phi$

$\Delta V = hk^3\Phi$

wherein

h1 designates the height at which a paraxial axial light ray strikes the first surface of the lens system including the aspherical surface;

h designates the height at which the paraxial axial light ray strikes the aspherical surface when the height h1 is 1;

k1 designates the height at which a paraxial off-

axis ray, passing through the center of the entrance pupil, strikes the first surface of the lens system including the aspherical surface;

k designates the height at which the paraxial off-axis light ray strikes the aspherical surface when the height k1 is -1;

N' designates the refractive index of a medium on the side of the image with respect to the aspherical surface; and

N designates the refractive index of a medium on the side of the object with respect to the aspherical surface.

[Embodiment 1]

Figures 1 through 6D show the first embodiment of the zoom lens system.

Figure 1 is the lens arrangement of the zoom lens system according to the first embodiment, and Table 1 shows the numerical data thereof. Figures 2A through 2D show aberrations occurred in the zoom lens system shown in figure 1 at the short focal length extremity. Figures 3A through 3D show aberrations occurred in the zoom lens system shown in figure 1 at the intermediate focal length when the lens groups are moved along the lens-group moving paths shown in figure 20. Figures 4A through 4D show aberrations occurred in the zoom lens system shown in figure 1 at the long focal length extremity.

The designators f, W, f_B, D4, D7 and D10 in Table 1 represent numerical data when the lens groups of the zoom lens system are moved according to the lens-group moving paths of figure 20.

Surface Nos. 1 through 4 represent the positive first lens group 10, surface Nos. 5 through 7 represent the negative second lens group 20, surface Nos. 8 through 10 represent the positive third lens group 30, surface Nos. 11 through 14 represent the negative fourth lens group 40. The diaphragm S is provided 1.69mm behind (on the image side) the third lens group 30 (surface No. 10).

The positive first lens group 10 includes a negative meniscus lens element having the concave surface facing toward the object and a positive lens element, in this order from the object.

The negative second lens group 20 includes cemented lens elements having a biconcave negative lens element and a positive lens element, in this order from the object.

The positive third lens group 30 includes cemented lens elements having a negative meniscus lens element having the convex surface facing toward the object and a positive lens element, in this order from the object.

The negative fourth lens group 40 includes a positive lens element and a negative lens element, in this order from the object.

On the other hand, figures 5A through 5D show aberrations occurred in the zoom lens system shown in figure 1 at the first (before switching) intermediate focal length in the short-focal-length side zooming range ZW when the lens groups are moved along the lens-group moving paths shown in figure 19; and figures 6A through 6D show aberrations occurred in the zoom lens system shown in figure 1 at the second (after switching) intermediate focal length in the long-focal-length side zooming range ZT when the lens groups are moved along the lens-group moving paths shown in figure 19.

Aberrations occurred in the zoom lens system, at the short focal length extremity (refer to figures 2A thorough 2D) and the long focal length extremity (refer to figures 4A thorough 4D), which is arranged to move along the lens-group moving paths of figure 19, are the same as those occurred in the zoom lens system which is arranged to move along the lens-group moving paths of figure 20.

The designators f, W, f_B, D4, D7 and D10 in Table 2 represent numerical data, arranged in the order of fw – fm1 – fm2 –ft, when the lens groups of the zoom lens system are moved according to the lens-group moving paths of figure 19.

The negative second lens group 20 and the positive third lens group 30 maintain the predetermined distance

d1 (= 3.50 mm) in the short-focal-length side zooming range ZW, and maintains the shortened distance d2 (= 0.50 mm) in the long-focal-length side zooming range ZT.

[Table 1]

FNo = 1:	5.8	10.6	12.5	
f	39.00	90.00	138.00	(Zoom Ratio = 3.54)
W	28.4	13.3	8.8	
f_B =	9.08	38.60	56.12	
D4 =	2.70	11.40	16.50	
D7 =	3.50	3.00	0.50	
D10 =	14.61	5.91	4.20	

Surf.No.	r	d	Nd	ν
1	-20.934	1.20	1.84666	23.8
2	-30.388	0.10		
3	35.358	3.10	1.48749	70.2
4	-37.768	D4		
5	-28.240	1.00	1.83481	42.7
6	12.194	2.80	1.80436	25.1
7	59.853	D7		
8	13.723	1.20	1.84666	23.8
9	9.658	4.20	1.58636	60.9
10*	-23.562	D10		
11*	75.872	2.80	1.58547	29.9
12*	-74.976	4.60		
13	-9.783	1.75	1.72785	53.2

14	-236.364	-

* designates the aspherical surface which is rotationally symmetrical with respect to the optical axis.

Aspherical surface data (the aspherical surface coefficients not indicated are zero (0.00)):

Surf.No.	K	A4	A6	A8
10	0.00	0.77770×10^{-4}	-0.22882×10^{-6}	-
11	0.00	0.81605×10^{-4}	-0.15678×10^{-5}	0.14854×10^{-7}
12	0.00	-0.14505×10^{-4}	-0.11330×10^{-5}	-

[Table 2]

FNo = 1:	5.8	9.0	10.3	12.5
f =	39.00	70.00	110.00	138.00
W =	28.4	16.9	10.8	8.8
f_B =	9.08	28.94	41.76	56.12
D4 =	2.70	7.50	15.00	16.50
D7 =	3.50	3.50	0.50	0.50
D10 =	14.61	7.88	5.93	4.20

[Embodiment 2]

Figures 7 through 12D show the second embodiment of the zoom lens system.

Figure 7 is the lens arrangement of the zoom lens system according to the second embodiment, and Table 3 shows the numerical data thereof. Figures 8A through 8D show aberrations occurred in the zoom lens system shown in figure 7 at the short focal length extremity. Figures

9A through 9D show aberrations occurred in the zoom lens system shown in figure 7 at the intermediate focal length when the lens groups are moved along the lens-group moving paths shown in figure 20. Figures 10A through 10D show aberrations occurred in the zoom lens system shown in figure 7 at the long focal length extremity.

The designators f, W, f_B, D4, D7 and D10 in Table 3 represent numerical data when the lens groups of the zoom lens system are moved according to the lens-group moving paths of figure 20.

The diaphragm S is provided 1.50mm behind (on the image side) the third lens group 30 (surface No. 10).

On the other hand, figures 11A through 11D show aberrations occurred in the zoom lens system shown in figure 7 at the first (before switching) intermediate focal length in the short-focal-length side zooming range ZW when the lens groups are moved along the lens-group moving paths shown in figure 19; and figures 12A through 12D show aberrations occurred in the zoom lens system shown in figure 7 at the second (after switching) intermediate focal length in the long-focal-length side zooming range ZT when the lens groups are moved along the lens-group moving paths shown in figure 19.

Aberrations occurred in the zoom lens system, at the short focal length extremity (refer to figures 8A thorough

8D) and the long focal length extremity (refer to figures 10A thorough 10D), which is arranged to move along the lens-group moving paths of figure 19, are the same as those occurred in the zoom lens system which is arranged to move along the lens-group moving paths of figure 20.

The designators f, W, f_B, D4, D7 and D10 in Table 4 represent numerical data, arranged in the order of fw – fm1 – fm2 –ft, when the lens groups of the zoom lens system are moved according to the lens-group moving paths of figure 19.

The negative second lens group 20 and the positive third lens group 30 maintain the predetermined distance d1 (= 3.30 mm) in the short-focal-length side zooming range ZW, and maintains the shortened distance d2 (= 0.50 mm) in the long-focal-length side zooming range ZT.

[Table 3]

FNo = 1:	5.8	9.9	12.8	
f	39.00	90.00	140.00	(Zoom Ratio = 3.59)
W	28.5	13.2	8.6	
f_B =	9.10	35.47	57.76	
D4 =	2.30	11.50	16.90	
D7 =	3.30	1.50	0.50	
D10 =	14.44	6.41	3.17	

Surf.No.	r	d	Nd	ν
1	-20.490	1.20	1.84666	23.8

2	-30.306	0.10		
3	36.119	3.10	1.48749	70.2
4	-36.119	D4		
5	-31.225	1.00	1.88300	40.8
6	11.466	2.68	1.80518	25.4
7	74.351	D7		
8	13.341	1.93	1.84666	23.8
9	9.336	4.20	1.58636	60.9
10*	-25.111	D10		
11*	43.284	2.80	1.58547	29.9
12*	-462.439	5.11		
13	-9.944	1.38	1.72916	54.7
14	-182.688	-		

* designates the aspherical surface which is rotationally symmetrical with respect to the optical axis.

Aspherical surface data (the aspherical surface coefficients not indicated are zero (0.00)):

Surf.No.	K	A4	A6	A8
10	0.00	0.69652×10^{-4}	-0.12665×10^{-6}	-
11	0.00	0.59835×10^{-4}	-0.92890×10^{-6}	0.10123×10^{-7}
12	0.00	-0.20328×10^{-4}	-0.80651×10^{-6}	-

[Table 4]

FNo = 1:	5.8	9.5	10.4	12.8
f =	39.00	70.00	110.00	140.00
W =	28.5	16.9	10.9	8.6

f_B =	9.10	28.00	42.02	57.76
D4 =	2.30	9.50	15.50	16.90
D7 =	3.30	3.30	0.50	0.50
D10 =	14.44	6.96	5.07	3.17

[Embodiment 3]

Figures 13 through 18D show the third embodiment of the zoom lens system.

Figure 13 is the lens arrangement of the zoom lens system according to the third embodiment, and Table 5 shows the numerical data thereof. Figures 14A through 14D show aberrations occurred in the zoom lens system shown in figure 13 at the short focal length extremity. Figures 15A through 15D show aberrations occurred in the zoom lens system shown in figure 13 at the intermediate focal length when the lens groups are moved along the lens-group moving paths shown in figure 20. Figures 16A through 16D show aberrations occurred in the zoom lens system shown in figure 13 at the long focal length extremity.

The designators f, W, f_B, D4, D7 and D10 in Table 5 represent numerical data when the lens groups of the zoom lens system are moved according to the lens-group moving paths of figure 20.

The diaphragm S is provided 1.66mm behind (on the image side) the third lens group 30 (surface No. 10).

On the other hand, figures 17A through 17D show

aberrations occurred in the zoom lens system shown in figure 13 at the first (before switching) intermediate focal length in the short-focal-length side zooming range ZW when the lens groups are moved along the lens-group moving paths shown in figure 19; and figures 18A through 18D show aberrations occurred in the zoom lens system shown in figure 13 at the second (after switching) intermediate focal length in the long-focal-length side zooming range ZT when the lens groups are moved along the lens-group moving paths shown in figure 19.

Aberrations occurred in the zoom lens system, at the short focal length extremity (refer to figures 14A thorough 14D) and the long focal length extremity (refer to figures 16A thorough 16D), which is arranged to move along the lens-group moving paths of figure 19, are the same as those occurred in the zoom lens system which is arranged to move along the lens-group moving paths of figure 20.

The designators f, W, f_B, D4, D7 and D10 in Table 6 represent numerical data, arranged in the order of fw – fm1 – fm2 –ft, when the lens groups of the zoom lens system are moved according to the lens-group moving paths of figure 19.

The negative second lens group 20 and the positive third lens group 30 maintain the predetermined distance d1 (= 3.30 mm) in the short-focal-length side zooming range

ZW, and maintains the shortened distance d2 (= 0.30 mm) in the long-focal-length side zooming range ZT.

[Table 5]

FNo = 1:	5.8	9.5	12.5	
f	39.00	90.00	138.00	(Zoom Ratio = 3.54)
W	28.5	13.3	8.8	
f_B =	9.29	37.17	56.99	
D4 =	2.26	12.17	15.99	
D7 =	3.30	2.20	0.30	
D10 =	14.95	6.14	4.22	

Surf.No.	r	d	Nd	ν
1	-21.073	1.20	1.84666	23.8
2	-30.778	0.10		
3	35.359	3.10	1.48749	70.2
4	-37.978	D4		
5	-28.159	1.00	1.83481	42.7
6	11.038	2.80	1.80518	25.4
7	56.333	D7		
8	13.375	1.20	1.84666	23.8
9	9.165	4.20	1.58636	60.9
10*	-23.493	D10		
11*	60.020	2.80	1.58547	29.9
12*	-105.639	4.92		
13	-9.841	1.31	1.72916	54.7
14	-149.853	-		

* designates the aspherical surface which is rotationally symmetrical with respect to the optical axis.

Aspherical surface data (the aspherical surface coefficients not indicated are zero (0.00)):

Surf.No.	K	A4	A6	A8
10	0.00	0.70528×10^{-4}	-0.19227×10^{-6}	-
11	0.00	0.78954×10^{-4}	-0.13420×10^{-5}	0.12806×10^{-7}
12	0.00	-0.49690×10^{-5}	-0.10601×10^{-5}	-

[Table 6]

FNo = 1:	5.8	8.0	10.4	12.5
f =	39.00	70.00	110.00	138.00
W =	28.5	16.9	10.8	8.8
f_B =	9.29	28.16	42.62	56.99
D4 =	2.26	9.72	14.01	15.99
D7 =	3.30	3.30	0.30	0.30
D10 =	14.95	7.49	6.20	4.22

The numerical values of each embodiment for each condition are shown in Table 7.

[Table 7]

	Embodiment 1	Embodiment 2	Embodiment 3
Condition (1)	0.40	0.39	0.41
Condition (2)	0.08	0.07	0.08
Condition (3)	0.61	0.59	0.60
Condition (4)	13.42	13.54	13.48
Condition (5)	13.42	13.54	13.48

Condition (6)	-27.78	-24.31	-26.24
Condition (7)	0.53	0.46	0.48

As can be understood from Table 7, the numerical values of the first through third embodiments satisfy conditions (1) through (7). Furthermore, as shown in the aberration diagrams, the various aberrations at each focal length are adequately corrected.

According to the above description, a zoom lens system, for a lens-shutter compact camera with a retractable lens barrel, having a zoom ratio Z (= fT/fW) of more than 3.5, can be achieved.